Conservation of Spices Germplasm in India*

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Genetic resources of crop plants include genepools of both domesticated and wild species. They are the reservoirs of useful genes, which could be of immense use for the genetic improvement of crops. During the past three decades awareness has been generated to identify, collect and conserve the fast depleting and irreplaceable crop genetic resources for use by present and future generations. According to Vavilov (1926), about 160 species of domesticated plants have originated in India. Among these, spices constitute a very important group of plants, which had its origin in India. These are high value crops with potential for large-scale export. Hence, it is imperative to collect and conserve the germplasm of spice crops.

There are many spices that are cultivated in India (Table 1). The important ones, particularly with relevance to our country are: black pepper (*Piper nigrum* L.), turmeric (*Curcuma longa* L.), ginger (*Zingiber officinale* Rosc.), cardamom (*Elettaria cardamomum* (L.) Maton), coriander (*Coriandrum sativum* L.), fenugreek (*Trigonella foenum-graecum* L.), fennel (*Foeniculum vulgare* Mill.), cumin (*Cuminum cyminum* L.), cinnamon (*Cinnamomum verum* Presl.), cassia (*Cinnamomum aromaticum* Nees), nutmeg (*Myristica fragrans* Houtt.), clove (*Syzygium aromaticum* (L.) Merr. & Perry), tamarind (*Tamarindus indicus* L.), kokam (*Garcinia indica* (Thouars) Choisy), Malabar tamarind (*Garcinia cambogia* (Gaertn.) Desr.), Mysore gamboge (*Garcinia xanthochymus* Hk. *f.* &Th.) and vanilla (*Vanilla planifolia* Jacks.). Of all the spices produced in India, chilli occupies the first place in terms of area, production and consumption. However, under the ICAR set up chilli is included under vegetables and hence, the present review does not cover this crop.

Seed spices mostly have orthodox seed, and can be easily conserved in seed genebanks. Vegetatively propagated spices and seed spices either with no seeds or with recalcitrant or intermediate seeds are conserved in field genebanks, *in vitro* genebanks and cryobanks.

Conservation of Spices in Field Genebank

Black Pepper

Black pepper (*Piper nigrum* L.) belonging to the family Piperaceae is an important spice that has its origin in the southern Western Ghats, specifically in Kerala. It is cultivated as a backyard crop as well as a commercial crop from coastal plains to elevations as high as 1500 m. The maximum cultivation in Kerala is noticed in Idukki and Wayanad districts. Two biotic factors, namely, foot rot disease and root knot nematode have greatly damaged the crop resulting in fast depletion of its genetic stock. Over 100 cultivars of black pepper have been reported from the southern Western Ghats along with 18 species distributed in the forests (Table 2). Deforestation has led to the depletion of the wild relatives of the crop. North-East, tropical and subtropical Himalaya, Eastern Ghats and northern Western Ghats need to be explored to collect more germplasm.

The Indian Institute of Spices Research (IISR), Kozhikode and National Bureau of Plant Genetic Resources (NBPGR) have given high priority for systematic collection and conservation of black pepper growing in the Western Ghats. In IISR, about 3,000 accessions of black pepper are conserved. The information about maintenance of germplasm in field genebank at various institutes is presented in Table 3.

The species-wise accessions of *Piper* L. being maintained in field genebank at NBPGR Regional Station, Thrissur and IISR, Kozhikkode are given in Table 4.

Turmeric

Turmeric (*Curcuma longa* L.) known as the 'yellow spice' is believed to have originated in India. Turmeric belongs to the family Zingiberaceae and has widespread occurrence in the tropics and subtropics of Asia. India has maximum

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Table 1. Various spice crops cultivated in India

S No.	Botanical name	Common name	Part used	Family
1.	*Acorus calamus* L.	Sweet-flag	Rhizome	Acoraceae
2.	*Allium cepa* L.	Onion	Bulb	Alliaceae
3.	*A. sativum* L.	Garlic	Bulb	Alliaceae
4.	*Alpinia galanga* Willd.	Greater galangal	Rhizome	Zingiberaceae
5.	*Amomum subulatum* Roxb.	Large cardamom, Sikkim cardamom, Nepal cardamom	Fruit, seed	Zingiberaceae
6.	*Anethum graveolens* L.	Dill	Fruit, leaf	Apiaceae
7.	*Apium graveolens* L.	Celery	Root	Apiaceae
8.	*Armoracia rusticana* Gaertn.	Horse-radish	Root	Apiaceae
9.	*Averrhoa carambola* L.	Carambola, star-fruit*	Fruit	Averrhoaceae
10.	*A. bilimbi* L.	Bilimbi, cucumber-tree*	Fruit	Averrhoaceae
11.	*Brassica juncea* (L.) Czernajev & Cosson	Indian mustard	Seed	Brassicaceae
12.	*Brassica nigra* (L.) Koch	Black mustard	Seed	Brassicaceae
13.	*Bunium persicum* (Bioss.) B. Fedtsh.	Black caraway	Seed, tuber	Apiaceae
14.	*Capparis spinosa* L.	Caper	Unopened flower bud	Capparidaceae
15.	*Capsicum frutescens* L., *C. annuum* L.	Chilli, capsicum	Fruit	Solanaceae
16.	*Carum bulbocastanum* L.	Black caraway	Fruit	Apiaceae
17.	*C. carvi* L.	Caraway	Fruit	Apiaceae
18.	*Cinnamomum bejolghota* Kosterm.	*Tejpat**	Leaf	Lauraceae
19.	*C. aromaticum* Nees	Cassia, Chinese cinnamon*	Bark, leaf	Lauraceae
20.	*C. impressinervium* Meissn.	*Tejpat**	Leaf	Lauraceae
21.	*C. tamala* (Buch-Ham.) Nees & Eberm.	Indian cassia, *tejpat**	Bark, leaf	Lauraceae
22.	*C. verum* Presl.	Cinnamon*	Bark	Lauraceae
23.	*Coriandrum sativum* L.	Coriander	Leaf, seed	Apiaceae
24.	*Crocus sativus* L.	Saffron	Stigma	Iridaceae
25.	*Cuminum cyminum* L.	Cumin	Fruit	Apiaceae
26.	*Curcuma longa* L.	Turmeric	Rhizome	Zingiberaceae
27.	*Elettaria cardamomum* (L.) Maton	Cardamom	Fruit, seed	Zingiberaceae
28.	*Foeniculum vulgare* Mill.	Fennel	Fruit	Apiaceae
29.	*Garcinia cambogia* (Gaertn.) Desr.	Malabar tamarind*	Fruit rind	Clusiaceae
30.	*Garcinia cowa* Roxb. ex DC.	Kowa*	Fruit rind	Clusiaceae
31.	*Garcinia xanthochymus* Hk. *f.* & Th.	Mysore gamboge*	Fruit rind	Clusiaceae
32.	*Garcinia indica* (Thouars) Choisy	Kokam*	Fruit rind	Clusiaceae
33.	*Hyssopus communis* L.	Hyssop	Leaf	Lamiaceae
34.	*Juniperus communis* L.	Juniper*	Berry	Cuppressaceae
35.	*Mentha arvensis* L.	Japanese mint	Leaf	Lamiaceae
36.	*Mentha spicata* L.	Spear mint, garden mint	Leaf	Lamiaceae
37.	*Mentha piperita* L.	Pepper mint	Leaf	Lamiaceae
38.	*Murraya koenigii* (L.) Sprengel	Curry leaf*	Leaf	Rutaceae
39.	*Myristica fragrans* Houtt.	Nutmeg, mace*	Kernel, aril	Myristicaceae
40.	*Nigella sativa* L.	Black cumin	Fruit	Ranunculaceae
41.	*Ocimum basilicum* L.	Sweet basil	Leaf	Lamiaceae
42.	*Origanum majorana* L.	Sweet marjoram	Leaf, flowering top	Lamiaceae
43.	*Origanum vulgare* L.	Marjoram	Leaf, flowering top	Lamiaceae
44.	*Papaver somniferum* L.	Opium poppy	Seed	Apiaceae
45.	*Petroselinum crispum* (Miller) Nyman ex A.W. Hill	Parsley	Seed	Apiaceae
46.	*Pimenta dioica* (L.) Merr.	Allspice, pimento*	Fruit, leaf	Myrtaceae
47.	*Pimpinella anisum* L	Aniseed	Fruit	Apiaceae
48.	*Piper nigrum* L.	Black pepper, white pepper	Fruit	Piperaceae
49.	*Punica granatum* L.	Pomegranate	Seed (dried with flesh)	Punicaceae
50.	*Rosmarinus officinalis* L.	Rosemary	Leaf	Lamiaceae
51.	*Salvia officinalis* L.	Sage	Leaf	Lamiaceae
52.	*Saturega hortensis* L.	Summer savory	Stem, leaf, flowering top	Lamiaceae
53.	*Syzygium aromaticum* (L.) Merr. & Perry	Clove*	Unopened flower bud	Myrtaceae
54.	*Synapsis alba* (L.) Biossier	White mustard, yellow mustard	Seed	Brassicaceae
55.	*Tamarindus indica* L.	Tamarind*	Fruit	Caesalpiniaceae
56.	*Thymus vulgaris* L.	Thyme	Leaf, flowering top	Lamiaceae
57.	*Trachyspermum ammi* (L.), Sprague ex Turrill	Bishops weed, *ajwain*	Fruit	Apiaceae
58.	*Trigonella foenum-graecum* L.	Fenugreek	Seed	Fabaceae
59.	*Vanilla planifolia* Jacks.	Vanilla	Pod	Orchidaceae
60.	*Zanthoxylum limonella* (Dennst.) Alston	Indian pepper tree*	Fruit	Rutaceae
61.	*Zingiber officinale* Rosc.	Ginger	Rhizome	Zingiberaceae

* Tree spices

Source: Modified from Ravindran *et al.* (2005)

Table 2. Species diversity of *Piper* L. in Western Ghats

S. No.	Species	Salient features
1.	*P. argyrophyllum* Miq.	Occurs at medium elevation in the peripheral areas of evergreen forests, becoming rare
2.	*P. attenuatum* Buch.-Ham. ex Miq.	A common species, occurs at low and medium elevation
3.	*P. barberi* Gamble	Included in the Red List of Threatened Vascular Plant Species as endangered, occurs in Tirunelveli forests, Tamil Nadu
4.	*P. betle* L.	Cultivated species but also occurs in forest
5.	*P. galeatum* (Miq.) C. DC.	Occurs at medium elevations, bold fruits
6.	*P. hapnium* Miq.	Very rare, endangered, occurring at low elevations, included in the Red List of Threatened Vascular Plant Species
7.	*P. hookeri* Miq.	Closely related to *P. hymenophyllum*, but less pubescent
8.	*P. hymenophyllum* Miq.	Occurs at medium to high elevations, pubescent species
9.	*P. longum* L.	Distributed all over India at low elevations, has creeping habit, medicinal value
10.	*P. pseudonigrum* Vela. & Amal.	Related to *P. nigrum* and very similar to *P. sugandhi* var. *brevipilis*
11.	*P. pykarahense* C. DC.	Reported from the Nilgiris, Tamil Nadu, included in the Red List of Threatened Vascular Plant Species
12.	*P. schmidtii* Hk. *f.*	Endangered species, occurs at high elevation above 1500 m in the Nilgiris, Tamil Nadu
13.	P. silentvalleyensis *Ravindran et al.*	New species, extremely rare, has bisexual flowers and minute fruit
14.	*P. sugandhi* Ravindran et al.	Closely related to *P. nigrum* and *P. pseudonigrum*
15.	*P. sugandhi* var. *brevipilis*	Similar to *P. sugandhi*
16.	*P. trichostachyon* (Miq.) C. DC.	A medium elevation species resembling *P. galeatum*
17.	*P. wightii* Miq.	The pepper of hill tops of Nilgiris, occurs only at high elevation around 2000 m
18.	*Piper* species (*unidentified*)	Newly discovered species from Nilgiris, related to *P. mullesua* Ham. ex D. Don, is bisexual and extremely rare

Source: Modified from Ravindran *et al.* (2000)

Table 3. Germplasm accessions of species of *Piper* L. being maintained in India

Institution	Accessions (no.)		
	Cultivated species	Wild and related species	Total
IISR, Kozhikkode, Kerala	2,079	890	2,969
NBPGR Regional Station, Thrissur, Kerala	183	67	250
Horticultural Research Station, Yercaud, Tamil Nadu	106	0	106
Pepper Research Station, Panniyur, Kerala	105	90	195
Pepper Research Station, Sirsi, Karnataka	75	21	96
Regional Agricultural Research Station, Chintapalli, Andhra Pradesh	26	29	55
All India Coordinated Research Project on Spices (AICRP) Centres	23	1	24
Total	**2,597**	**1,098**	**3,695**

area under its cultivation and the total production is around 90% of the world produce. The genetic erosion in the crop and its related species is mainly due to changes in cropping pattern in conventional areas of its cultivation and due to deforestation and habitat destruction.

Collection and conservation of turmeric germplasm are pursued actively by IISR, NBPGR and many other institutes (Table 5).

The field genebank at NBPGR Regional Station, Thrissur, has 889 accessions of *Curcuma* Roxb. germplasm including cultivated (627 accessions) and wild (262 accessions) (Tables 6 and 7, respectively). There is an urgent need for collecting and conserving the wild species reported to occur in the North-East and eastern region of the country.

Characterization and evaluation of germplasm of species of *Curcuma* were carried out at NBPGR Regional Station, Thrissur. Forty-four accessions of turmeric set seeds in Thrissur condition and these can be used in conventional breeding programmes. Additionally, several accessions of turmeric were found to be tolerant to scale insect and shoot borer under field conditions (Velayudhan and Liji 2003).

Ginger

Ginger (*Zingiber officinale* Rosc.) belongs to the family Zingiberaceae and is an important spice crop of India. It is cultivated on an area of 67,000 ha with a productivity of 3477 kg/ha. It has a good export value for its medicinal properties. The species of *Zingiber* Boeh. occurring in India are listed in Table 8. The current national holdings of ginger germplasm are given in Table 9.

Further details about the area of collection of wild species of *Zingiber* and cultivated ginger, conserved in

Table 4. Number of accessions of different species of *Piper* L. being maintained in field genebanks at NBPGR Regional Station, Thrissur and IISR, Kozhikode

S.No.	Species	Accessions (no.)		Area of Collection
		NBPGR	IISR	
1.	*P. arboreum*	1	–	Introduction from S. America
2.	*P. argyrophyllum* Miq.	11	56	Kerala, Karnataka, Tamil Nadu
3.	*P. attenuatum* Buch.-Ham. ex Miq.	5	74	Kerala, Karnataka, Tamil Nadu
4.	*P. bababudani* Rahiman et Nair	2	10	Karnataka
5.	*P. barberi* Gamble	–	2	Kerala, Tamil Nadu
6.	*P. betle* L.	9	14	Kerala, Karnataka, Tamil Nadu
7.	*P. chaba* Hunter	2	–	Kerala
8.	*P. colubrinum* Link	1	1	Introduction from S. America
9.	*P. galeatum* (Miq.) C. DC.	3	38	Kerala, Karnataka, Maharashtra
10.	*P. hapnium* Miq.	–	4	Kerala, Karnataka
11.	*P. hookeri* Miq.	–	1	Karnataka
12.	*P. hymenophyllum* Miq.	1	35	Kerala, Karnataka
13.	*P. longum* L.	21	41	Kerala, Karnataka, Tamil Nadu
14.	*P. magnificum* Trel.	1	–	Introduction from S. America
15.	*P. mullesua* Ham. ex D. Don	–	20	Kerala, Karnataka, Tamil Nadu
16.	*P. ornatum* NE Br.	–	1	Kerala
17.	P. peepuloides	–	1	West Bengal
18.	*P. pseudonigrum* Vela. and Amal.	2	–	Kerala
19.	*P. nigrum* L.	185	1237	Kerala, Karnataka, Tamil Nadu
20.	*P. sarmentosum* Roxb. ex Hunt.	–	1	Andaman and Nicobar
21.	*P. silentvalleyensis* Ravindran *et al.*	–	1	Tamil Nadu
22.	*P. sugandhi* Ravindran *et al.*	–	75	Kerala, Tamil Nadu
23.	*P. thomsonii*	–	1	West Bengal
24.	*P. trichostachyon* (Miq.) C. DC.	2	19	Kerala, Karnataka, Tamil Nadu

Table 5. Germplasm holding of turmeric and related species in the field genebanks in India

S.No.	Institution	Accessions (no.)
1.	IISR, Kozhikode, Kerala	899
2.	NBPGR Regional Station, Thrissur, Kerala	889
3.	TNAU, Coimbatore, Tamil Nadu	255
4.	Orissa University of Agriculture and Technology (OUAT), High Altitude Research Station, Pottangi, Orissa	193
5.	Regional Agriculture Research Station (RARS), Jagtial, Andhra Pradesh	189
6.	Dr Y.S. Parmar University of Horticulture and Forestry (YSPUHF), Solan, Himachal Pradesh	172
7.	Uttar Banga Krishi Vishwa Vidyalaya (UBKVV), Pundibari, West Bengal	142
8.	Tamil Nadu Agricultural University (TNAU) Horticultural Research Station, Bhavanisagar, Tamil Nadu	124
9.	Narendra Dev University of Agriculture and Technology (NDUAT), Faizabad, Uttar Pradesh	102
10.	Rajendra Agriculture University (RAU), Dholi, Bihar	76
11.	Indira Gandhi Agricultural University (IGAU) Regional Station, Raigarh, Chhattisgarh	61
	Total	**3102**

the field genebank at NBPGR Regional Station, Thrissur are presented in Tables 10 and 11, respectively.

Cardamom

In India, cardamom [*Elettaria cardamomum* (L.) Maton] occurs wild in its native state of Kerala only, but cultivated in the tropical evergreen forests of the southern Western Ghats and has common occurrence in the Silent Valley and Cardamom Hill forests. It consists of three morphologically distinct types, namely, Malabar, Mysore and *Vazhukka*. It is propagated both by seed and suckers. Variability in the natural populations is limited, probably because of it belonging to the monotypic genus in the region. Conservation of cardamom genetic resources was initiated in the 1960s and now they are being conserved at four centers (Table 12). A total of 1,419 accessions of cardamom and its wild relatives is being conserved in the field gene banks of various institutes/centers.

Tree Spices

There are many tree spices in India, some are native whereas others are introduced (Table 1). Of these, nutmeg, clove and cinnamon are widely grown in the states of Kerala, Karnataka and Tamil Nadu, and all the three are recent introductions. Allspice is also a recent introduction, but is less popular. Tamarind is a naturalized tree spice grown widely whereas, curry leaf and species of *Garcinia* L., namely, Malabar tamarind, kokam and

Table 6. Areas of collection of 627 accessions of cultivated turmeric being maintained at NBPGR Regional Station, Thrissur

State	District
Andhra Pradesh	Sreekakaulam, Visakapatnam, West Godavari, Vizianagaram
Arunachal Pradesh	Kohir
Assam	Goalpara
Himachal Pradesh	Shimla, Solan, Panchkula, Nahan, Bilaspur, Kangra, Dharmasthala
Jharkand	Ranchi, East Singbhum, Chatra
Karnataka	Shimoga, Kodagu, Dakshin Kannad, Dharwad
Kerala	Kannur, Ernakulam, Kasargod, Kottayam, Malappuram, Wayanad, Palakkad, Thrissur, Kozhikode, Thiruvananthapuram, Pathanamthitta, Idukki, Alappuzha .
Madhya Pradesh	Bilaspur
Maharashtra	Akola
Manipur	Imphal
Meghalaya	Shillong
Orissa	Kondhamal, Ganjam, Gajapati, Malkangiri, Koraput, Phulbani
Sikkim	Gangtok, East Sikkim
Tamil Nadu	Tirunelveli, Nilgiris, Erode, Pudukottai, Tiruchirappalli, Kanyakumari, Thanjavur, South Arcot, Coimbatore
Uttar Pradesh	Gorakhpur, Dehra Dun
West Bengal	Jalpaiguri

Table 7. Germplasm accessions of wild species of *Curcuma* Roxb. being maintained in the field genebank at NBPGR Regional Station, Thrissur

S. No.	Species	Accessions (no.)	Area of collection
1.	*Curcuma aeruginosa* Roxb.	4	Orissa, Sikkim
2.	*C. amada* Roxb.	48	Andhra Pradesh, Orissa, Kerala, Karnataka, Tamil Nadu, Uttar Pradesh
3.	*C. amarissima* Rosc.	1	–
4.	*C. albiflora* Thw.	3	Karnataka
5.	*C. aromatica* Salisb.	37	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Uttar Pradesh
6.	*C. aurantiaca* Van Zijp	9	Kerala
7.	*C. brog* Val.	2	–
8.	*C. caesia* Roxb.	5	Jharkhand, Sikkim
9.	*C. cannanorensis* Ansari & Nair	1	Kerala
10.	*C. comosa* Roxb.	2	–
11.	*C. coriacea* Mangaly & Sabu	1	Kerala
12.	*C. decipiens* Dalz.	3	Karnataka, Kerala
13.	*C. ferruginea* Roxb.	2	Sikkim, West Bengal
14.	*C. harita* Sabu & Mangaly	14	Andhra Pradesh, Kerala
15.	*C. karnatakensis* Amal. *et al.*	1	Karnataka
16.	*C. kudagensis* Vela. *et al.*	5	Karnataka
17.	*C. lutea* (Ansari *et al.*) Amal. *et al.*	3	Karnataka, Kerala
18.	*C. malabarica* Vela. *et al.*	38	Karnataka, Kerala, Tamil Nadu
19.	*C. montana* Roxb.	1	Andhra Pradesh
20.	*C. neilgherensis* Wight.	4	Kerala, Tamil Nadu
21.	*C. nilamburensis* Vela. *et al.*	3	Kerala, Tamil Nadu
22.	*C. pseudomontana* Grah.	2	Kerala
23.	*C. raktakanta* Mangaly & Sabu	7	Kerala
24.	*C. soloensis* Val.	1	West Bengal
25.	*C. vamana* Sabu & Mangaly	3	Kerala
26.	*C. zedoaria* (Christm.) Rosc.	47	Orissa, Kerala, Tamil Nadu
27.	*Curcuma* species (unidentified)	15	Kerala
	Total	**262**	

Mysore gamboge are indigenous and grown to a certain extent in India.

***Nutmeg*:** Nutmeg (*Myristica fragrans* Houtt.) belongs to the family Myristicaceae, and is the only plant that produces two separate spices – nutmeg and mace. The former is the kernel of the seed and the latter, the aril covering the seed. *Myristica amygdalina* Wall., *M. andamanica* Hk., *M. attenuata* Wall. ex Hk. *f.* & Th., *M. beddomei* King., *M. fatua* Houtt. var. *magnifica* (Bedd.) Sinclaire, *M. gibbosa* Hk., *M. glabra* Bl., *M. glaucescens* Hk., *M. irya* Gaertn., *M. kingii* Hk., *M. longifolia* Wall. and *M. malabarica* Lam. occur in India. Most of these are endemic to the Indo-Malayan region including the Western Ghats. At IISR, Kozhikkode, 471 accessions are maintained in the field genebank.

Clove: Clove [*Syzygium aromaticum* (L.) Merr. & Perry] belongs to the family Myrtaceae. It is a native of Moluccas Islands (Indonesia). Under natural conditions in Moluccas

Table 8. Species of *Zingiber* Boeh. occurring in India

S.No.	Species	S. No.	Species
1.	*Z. officinale* Rosc.	10.	*Z. ligulatum* Roxb.
2.	*Z. zerumbet* (L.) Sm.	11.	*Z. spectabilis* Griff.
3.	*Z. purpureum* Rosc.	12.	*Z. clarkii* King ex Benth.
4.	*Z. roseum* (Roxb.) Rosc.	13.	*Z. marginatum* Roxb.
5.	*Z. wightianum* Thw.	14.	*Z. intermedium* Baker
6.	*Z. macrostachyum* Dalz.	15.	*Z. chrysanthum* Rosc.
7.	*Z. cernuum* Dalz.	16.	*Z. rubens* Roxb.
8.	*Z. capitatum* Roxb.	17.	*Z. squarrosum* Roxb.
9.	*Z. cylindricum* Moon	18.	*Z. elatum* R. Br.

Table 9. Conservation of germplasm of ginger in field genebanks in India

Institution	Accessions (no.)
IISR, Kozhikode, Kerala	645
YSPUHF, Solan, Himachal Pradesh	271
NBPGR Regional Station, Thrissur, Kerala	125
OUAT High Altitude Research Station, Pottangi, Orissa	172
RAU, Dholi, Bihar	103
UBKVV, Pundibari, West Bengal	31
NDUAT, Faizabad, Uttar Pradesh	29
IGKVV, Raigarh station.	35
Department of Horticulture, Sikkim	58
CARI, Port Blair	33
Total	**1502**

Table 10. Wild species of *Zingiber* being maintained in the field genebank at NBPGR Regional Station, Thrissur

S.No.	Species	Accessions (no.)	Areas of collection
1.	*Z. cernuum* Dalz.	1	Andhra Pradesh
2.	*Z. neesanum* (Grah.) Ramam.	4	Karnataka, Kerala, Tamil Nadu
3.	*Z. purpureum* Rosc.	2	Andhra Pradesh, Orissa
4.	*Z. rubens* Roxb.	2	Orissa
5.	*Z. wightianum* Thw.	1	Kerala
6.	*Z. zerumbet* (L.) J.E. Smith	14	Andhra Pradesh, Kerala, Karnataka, Tamil Nadu
	Total	**24**	

Table 11. Area of collection of 125 accessions of cultivated ginger being maintained at NBPGR Regional Station, Thrissur

State	District
Andhra Pradesh	Vishakapatnam, Vizianagaram
Himachal Pradesh	Sirmour
Jharkhand	Lohardaga, Ranchi
Karnataka	Dharwad
Kerala	Ernakulam, Idukki, Palakkad, Thrissur, Wayanad
Orissa	Koraput, Rayagada
Tamil Nadu	Namakkal
Uttaranchal	Champawat, Naini Tal, Pauri Garhwal

both clove producing (aromatic) and non-clove producing (non-aromatic) trees co-exist. Clove is grown as an intercrop in many households in Kerala and Karnataka. Some pure plantations exist in Kanyakumari district of Tamil Nadu and Thiruvananthapuram district of Kerala and are commonly planted on large scale in tea estates located at low to medium elevations. Because of the limited introductions that have taken place and self-pollinating nature of the crop, variability is very limited. A total of 215 accessions is conserved in the field genebank at IISR, Kozhikode.

***Cinnamon and Cassia*:** The true cinnamon is obtained from *Cinnamomum verum* Presl., belonging to the family Lauraceae. It is indigenous to Sri Lanka. The cassia cinnamon is obtained from various sources, the most important is *C. aromaticum* Nees (Chinese cinnamon, cassia or Chinese-cassia). The other cassia cinnamons are: Indonesian-cassia or Batavia cinnamon or Batavia-cassia [*C. burmanii* (Nees & T. Nees) Bl.], Saigon cinnamon or Saigon-cassia (*C. loureirii* Nees) and Indian-cassia or Indian-bark or *tejpat* [*C. tamala* (Buch.-Ham.) Nees & Eberm.]. Kostermans (1983) reported 13 species from South India including true cinnamon, most of them from the Western Ghats. The endemic species are *C. macrocarpum* Hk. *f.*, *C. malabathrum* (Burm. *f.*) Bl., *C. nicolsonianum* Manilal & Shylaja, *C. riparium* Gamble, *C. keralaense* Kosterm., *C. travancoricum* Gamble, *C. wightii* Meiss., *C. heyneanum* Nees, *C. gracile* (Miq.)

Table 12. Holdings of cardamom germplasm in India

Institution	Accessions (no.)		
	Cultivated	Wild relatives	Total
IISR Cardamom Research Centre, Apangala, Karnataka	326	13	339
Indian Cardamom Research Institute, Myladumpara, Kerala	673	23	696
AICRPS Centre, Pampadumpara, Kerala	104	15	119
AICRPS Centre, Mudigere, Karnataka	263	2	265
Total	**1366**	**53**	**1419**

Source: Modified from Ravindran *et al.* (2005)

Hk. *f.*, *C. chemungianum* Mohan and Henry. The non-endemic species are *C. citriodorum* Thw., *C. filipedicellatum* Kosterm., *C. goaense* Kosterem., *C. perrottetii* Meiss., *C. sulphuratum* Nees and *C. walaiwarense* Kosterm. The IISR, Kozhikkode maintains 35 accessions of cinnamon in the field genebank.

The genetic resources of cinnamon is being taken up at the Indian Institute of Spices Research, Kozhikode, Kerala Agricultural University at its Regional Research Station at Odakkali; by the Tamil Nadu Agricultural University at its Horticulture Research Station, Yercaud; by the Regional Research Laboratory, Bhubaneshwar; and by the Konkan Krishi Vidyapeeth at Vengurula. The IISR, Kozhikkode maintains in its genebank 166 cultivated types of *C. verum*, 35 related/ wild types and 14 exotic accessions. In addition, IISR, Kozhikkode also maintains a collection of Chinese cassia germplasm (*Cinnamomum aromaticum*) (Ravindran et al. 2004).

***Malabar tamarind, Kokam and Mysore gamboge*:** These crops belong to the genus *Garcinia* L. (Clusiaceae) and are found wild in evergreen or semi-evergreen forests of Western Ghats in South Maharashtra extending southwards to Karnataka, Kerala and Tamil Nadu. The genus *Garcinia* has 35 indigenous species with 3 taxonomic varieties and 3 exotic species in India. Seventeen species are endemic to India, of which seven are in Western Ghats, six in Andaman and Nicobar Islands and four in North-East India. These are less-known edible fruits, seeds of which yield fatty oils and fruit rind used as important spice in Peninsular Indian culinary preparations.

Malabar tamarind [*Garcinia cambogia* (Gaertn.) Desr.] is a multipurpose tree spice crop grown in the homesteads of Kerala for its acidic edible fruit, the rind of which is dried and used as a garnish in fish curries. It is endemic to the evergreen forests of southern Western Ghats and Sri Lanka. Dried rind lowers blood lipids and paves way for slower weight loss and supports body's natural appetite suppression mechanism. Resin of Malabar tamarind is principally used as a pigment in miniature paintings and watercolours, besides its medicinal use as a purgative. Fruit rind is hydragogue, anthelmintic and emetic, particularly in dropsy. It is employed in veterinary medicine as a rinse for diseases of mouth in cattle. Its rind possesses marked antiseptic properties (Akhtar Husain *et al.*, 1992). It is also used for polishing gold and silver ornaments and as a substitute for acetic acid for coagulation of rubber latex. The seed oil is used in medicine and the gum also makes a good varnish (Singh, 1993). The presence of HCA [(-) hydroxy citric acid] in *G.cambogia* was first reported by Lewis and Neelakandan (1965). Antony *et al.* (1998) performed quantitative analysis of HCA and HCAL [(-) hydroxy citric acid lactone] in *G.cambogia* and *G.indica* and estimated the presence of 19 to 26% of total acids in fruits. This natural HCA is a potent metabolic regulator of obesity and it also lowers blood lipids such as cholesterol and triglycerides by triggering the fatty acid oxidation in the liver via thermogenesis. It mobilizes body's fat stores and dissolves fat in the liver and also throughout the body paving way for weight management (Lowerstein, 1971; Sullivan *et al.*, 1972; Sullivan *et al.*, 1974 and Sullivan and Triscari, 1977). Administration of HCA promotes lipid oxidation and spares carbohydrate utilization in mice at rest and during running. It has antiulcerogenic effect i.e. it decreases acidity, increases the mucosal defense in the gastric areas and it prevents gastro-mucosal injury (Mahendran *et al.*, 2002a, Mahendran *et al.*, 2002b). Sarah *et al.*, 1992 studied the pattern of flowering and flower development and reported that the pattern of flower development from bud emergence to anthesis was found to be different in the case of male and female flowers. The bisexual flower bud was found to follow a sigmoid pattern, with distinct stages of development whereas the male flower bud showed a linear pattern of development. They have also reported bagging of bisexual flowers before flower opening, which gave fruit setting of only 20 per cent, thus showing that the trees are mostly cross pollinated. The seeds of *G.cambogia* are recalcitrant (Chacko and Chandrasekhara Pillai, 1997). The seed coat of Malabar tamarind is the important mechanical barrier, which delays the germination. The viability of the seeds can be retained for about one year by storing the seeds in moist sand or sawdust in open condition. The germination percentage of the seeds can be improved by treating them with gibberellic acid (Mathew and Sarah, 1995). It is increasingly becoming important industrially, commercially and medicinally, but not fully exploited. Germplasm accessions of this species are maintained at NBPGR Regional Station, Thrissur; Regional Agricultural Research Station (Kerala Agricultural Univeristy), Kumarakom, Kottayam; and District Agricultural Farm, Taliparamba, Kannur.

Kokam [*Garcinia indica* (Thouars) Choisy] is endemic to southern Western Ghats and probably originated as a crop in south Maharashtra and western Karnataka region, the fruit rind is used as a spice in south Maharashtra

and Goa. Fresh fruit rind with sugar is used in making a soft drink in Goa and western Karnataka. Edible butter obtained from the seeds is used in south Maharashtra and western Karnataka. Germplasm accessions of this species are maintained at NBPGR Regional Station, Thrissur and the Punjabrao Krishi Vidyapeeth, Dhapoli, Maharashtra.

Mysore gamboge (*Garcinia xanthochymus* Hk. *f.* & Th.) is another important but less-known tree spice, which can be commercially exploited for its fruit rind. Fruit rind is used as a spice to garnish fish curry and vegetarian preparations in coastal Karnataka. A native of India and Myanmar, it is widely distributed in the eastern Himalaya, Assam, West Bengal, Bihar, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra and Andaman Islands. About 4 years old seedlings of *G.xanthochymus* are useful as rootstock for grafting and inarching mangosteen; sometimes grown in gardens as an ornamental tree for its dense foliage (Singh, 1993).

Table 13 presents the information on germplasm accessions of three species of *Garcinia* conserved in the field genebank at NBPGR Regional Station, Thrissur. Further collection of elite germplasm accessions of all the useful species of *Garcinia* is to be made from the states of Karnataka, Tamil Nadu, Kerala, Maharashtra, Goa, North-East India, Eastern India and Andaman & Nicobar Islands.

Conservation of Spices in Seed Genebank and Cryo-genebank

Seed Spices

The major seed spices grown in India are coriander, cumin, fennel, fenugreek, celery, bishops weed or *ajwain*, dill, caraway, black caraway, black cumin, white mustard, black mustard and Indian mustard. Among them, only coriander, cumin, fennel and fenugreek are grown on a commercial scale. The main seed spice growing states are Andhra Pradesh, Tamil Nadu, Gujarat, Rajasthan, Uttar Pradesh, Madhya Pradesh and Haryana. Cultivation of the remaining seed spices is limited to certain areas only.

Details of germplasm of commercially grown seed spices conserved in the seed genebanks at different centers are given in Table 14.

In addition to the above, seed spices are also conserved using the technique of cryopreservation, i.e. conservation at ultra-low temperature such as that of liquid nitrogen (-196°C). Cryopreservation offers long-term conservation. A total of 55 accessions of species of *Amomum* Roxb. (2), *Anethum* L. (3), *Cinnamomum* Schaeffer (1), *Cuminum* L. (1), *Elettaria* Maton (2), *Foeniculum* Mill. (4), *Illicium* L. (1), *Piper* L. (40) and *Trachyspermum* Link (1) are cryopreserved as seeds in the cryo-genebank at NBPGR, New Delhi.

Table 13. *Garcinia* species (Malabar tamarind, kokam and Mysore gamboge) maintained in field genebank at NBPGR Regional Station, Thrissur

Species	Accessions (no.)	Area of collection
Garcinia cambogia (Gaertn.) Desr.	136	Goa, Karnataka, Kerala, Tamil Nadu
Garcinia indica (Thouars) Choisy	38	Goa, Karnataka, Kerala, Tamil Nadu
Garcinia xanthochymus Hk. *f.* & Th.	12	Karnataka, Kerala
Total	**186**	

Table 14. Germplasm holdings of commercially grown seed spice crops

Centre	Accessions (no.)			
	Coriander	Cumin	Fennel	Fenugreek
NBPGR, New Delhi*	293	8	3	9
Rajasthan Agricultural University Agricultural Research Station, Jobner	761	323	193	337
Gujarat Agricultural University, Jagudan	101	176	141	52
TNAU, Coimbatore	410	-	-	262
Acharya NG Ranga Agricultural University, Guntur	230	-	-	124
RAU, Dholi	102	-	40	103
NDUAT, Kumarganj	29	19	15	17
Chaudhary Charan Singh Haryana Agricultural University, Hisar	-	-	40	-
IGAU, Raigarh	20	-	-	13
Total 1,946	526	431	917	

*Conserved for long-term as base collections at -20°C, other institutes maintain germplasm for medium-term storage as active collections
Adapted from Ravindran *et al.* (2005)

Conservation of Spices in *In Vitro* Genebank

With the extensive development of innovative tissue culture techniques, *in vitro* conservation of vegetatively propagated species has been proposed as a safer alternative to the field genebank. Vegetatively propagated spice crops such as ginger, turmeric, black pepper and vanilla were given priority for their *in vitro* conservation at NBPGR, as a supplementary strategy for the field genebank conservation. Simple micro-propagation and *in vitro* conservation protocols were developed for species of *Zingiber, Curcuma, Piper* (Tyagi *et al.*, 1998) and *Vanilla*. Germplasm accessions of these crops were collected from various geographical regions of the country and conserved in the *in vitro* genebank at NBPGR, New Delhi (Table 15). The methods of conservation adopted in each crop are discussed below.

Table 15. Details of germplasm of spices in *in vitro* genebank at NBPGR, New Delhi

Crops	Accessions (no.)	Area of collection
Zingiber	30	North-East India
	73*	Kerala
	6	Uttar Pradesh
	38	Himachal Pradesh
	4	Andhra Pradesh
	7	Nepal
	5	Orissa
	63	Others
Curcuma	15	Kerala
	3	Tamil Nadu
	22	North-East India
	8	Himachal Pradesh
	12	Andhra Pradesh
	3	Orissa
	28	Others
Piper	35*	Kerala
Elettaria	5	Kerala
Vanilla	4	Kerala

* Includes 53 accessions of ginger and 28 of black pepper conserved at NBPGR Regional Station, Thrissur

Ginger

In *Zingiber* species, 226 accessions belonging to *Z. casumunar, Z. cernuum, Z. montanum, Z. nimnonii, Z. officinale, Z. roseum, Z. wightianum* and *Z. zerumbet* have been conserved by sub-culturing after 8-11 months at 25°C on MS (Murashige and Skoog, 1962) + 2.5 mg/l BAP medium (Table 15) at NBPGR, New Delhi. Use of *in vitro*-induced rhizomes for extending the storage period was also explored. Although, the shoots turned yellow in 15 months, the micro-rhizomes remained green up to 14-24 months (depending upon the accession) at 25°C on MS + 0.1 mg/l NAA + 1 mg/l BAP (Bhat *et al.*, 1994). Over 30% of rhizomes were capable of sprouting in soil after 24 months of storage. This approach appears to be novel and least stressful.

Turmeric

Germplasm of 91 accessions of *Curcuma* L., including 21 morphotypes of *C. longa* L.; and those of *C. aeruginosa* Roxb., *C. amada* Roxb., *C. amarissima* Rosc., *C. angustifolia* Roxb., *C. aromatica* Salisb., *C. brog* Val., *C. caesia* Roxb., *C. latifolia* Rosc., *C. malabarica* Vela. *et al.*, *C. raktakanta* Mangaly & Sabu, *C soloensis* Val., *C. zedoaria* (Christm.) Rosc. and unidentified species of *Curcuma* are conserved in *in vitro* by sub-culturing after every 8-11 months on MS + 2.5 mg/l BAP at 25 ± 2°C.

The data on shoot regeneration and conservation period revealed that the optimum medium for shoot regeneration and conservation is not necessarily the same. Optimum media for plantlet regeneration and medium-term conservation for individual species of *Curcuma* are reported by Tyagi *et al.* (2004). The success of any *in vitro* conservation programme depends on simple and reproducible protocol. The protocol should be applicable for a large number of accessions. Simple and reproducible protocol used for conserving the s hoots of ginger germplasm on MS + 2.5 mg/l BAP, was also used for conservation of *Curcuma* species successfully.

Table 16. Conservation of spice germplasm in *in vitro* genebanks

Genera of spice crops	NBPGR, New Delhi		IISR, Kozhikkode	
	No. of accessions	Optimum subculture period (months)	No. of accessions	Optimum subculture period (months)
Zingiber	226*	8-24**	70	12
Curcuma	91	8-10	120	12
Piper	35*	12-22	26	12
Elettaria	5	8-10	35	12
Vanilla	4	8-10	215	18-19

* Includes 53 and 28 accessions of ginger and black pepper, respectively, conserved at NBPGR Regional Station, Thrissur
**Conservation period for *in vitro*-induced micro-rhizomes is from 14 to 24 months

Piper *species*

Germplasm of one accession each of black pepper (*Piper nigrum)* and related wild species, namely, *P. barberi, P. betel, P. colubrinum, P. hapnium* and *P. longum* has been maintained for 12-22 months on half-strength MS + 0.1 mg/l IAA at 25^{0}C in the *in vitro* genebank at NBPGR, New Delhi. Additionally, cultures of 28 accessions of black pepper are also conserved at NBPGR Regional Station, Thrissur. Various growth substances were tested for increasing the subculture period of *Piper* species. *Piper longum* requires sub-culturing at 12 months interval, whereas other species could be stored for up to 22 months using the axillary buds as explants cultured on 1/2 MS + 0.1 mg/l IAA.

Vanilla and Cardamom

The NBPGR presently has cultures of 4 accessions of vanilla (*Vanilla planifolia*) and 5 accessions of cardamom (*Elettaria cardamomum*) in its *in vitro* genebank at New Delhi. The multiplication medium used for vanilla is MS + TDZ (0.01 mg/l). *In vitro* conservation protocol was studied in cultures of vanilla, using two polyamines - putrescine and spermidine. The cultures of vanilla could be conserved up to 10 months on MS + 0.25 mg/l putrescine (Tyagi *et al.*, 2001). The conservation medium being used for cardamom at NBPGR, New Delhi is MS + 2.5 mg/l BAP, which is similar to that for turmeric and ginger. All the accessions of cardamom can be stored up to 7 months in this medium.

By employing slow growth methods, germplasm accessions of species of *Zingiber, Curcuma, Piper, Vanilla* and *Elettaria* are being conserved in the *in vitro* genebank by sub-culturing the suitable explants at NBPGR and IISR (Table 16). Even if the intervals between transfers are greatly extended, medium-term conservation techniques employing tissue culture poses considerable problems in management of large collections. Alternative techniques, which minimize the need for germplasm maintenance, have to be developed. Thus, cryopreservation is an obvious and preferred choice for long-term conservation. Work on cryopreservation of shoot apices, somatic embryos, buds from *in vitro*-induced rhizomes of ginger and axilliary buds of *Piper* species is in progress, using encapsulation-dehydration, vitrification and encapsulation-vitrification techniques.

Monitoring the Genetic Stability of *In vitro*-conserved Germplasm

Tissue culture system is vulnerable to genetic variation. Conservation of germplasm, maintaining genetic stability is of paramount importance in crop improvement programme. Electrophoretic analysis of isozymes has been used for detecting the variation in *in vitro*-conserved germplasm of *Curcuma* species. Isozymes of acid phosphatase, esterase, glutamine synthetase, malate dehydrogenase, polyphenol oxidase, catalase and superoxide dismutase were investigated electrophoretically to compare 19 morphotypes of *C. longa* and 5 species of *Curcuma* (*C. caesia, C. longa, C. raktakanta, C. soloensis* and an unidentified species of *Curcuma*) maintained in earthen pots (*in vivo*-conserved) and same species conserved in tissue culture (*in vitro*-conserved) for the same period. A high degree of polymorphism was observed among all 5 species and the 19 morphotypes of turmeric confirming the genetic basis of morphological variation in these accessions. However, no significant variation was observed between *in vivo*-conserved and *in vitro*- conserved plants on the basis of 7 isozymes tested (Tyagi *et al.*, 2000). Random amplified polymorphic DNA (RAPD) analysis was also done for 20 morphotypes of turmeric and 12 species of *Curcuma* with various conditions. The primers have been identified which gave good polymorphism with 3-8 bands. No significant variation was observed between *in vitro*-conserved and *in vivo*-conserved germplasm of *Curcuma*.

Future Perspectives

1. Although a large number of germplasm accessions of spices has been collected, still there is need to identify the areas and crops to fill the gaps in available collection.
2. Since genetic erosion is a continuous process, conservation of germplasm is imperative till other effective methods of evaluation and utilization are employed.
3. Long-term conservation facilities are available at NBPGR. A large number of accessions of seed spices are being maintained at various centres as active collection, which needs to be conserved on priority in the National Genebank on a long-term basis.
4. Conservation of germplasm of vegetatively propagated spices in the *in vitro* genebank is necessary as safety duplicates of field genebank. Priority crops and viruses are to be identified, and techniques for virus

indexing and elimination should be standardized for virus-free conservation of germplasm.

5. A large number of accessions of various spice crops have been conserved in the genebanks. Characterization and evaluation of these accessions are important. Molecular characterization could be very effective to determine the uniqueness of each accession.
6. It is a valid concern that spice germplasm is inadequately evaluated and consequently under-utilized. This can be addressed to some extent by identifying a set of core collections, which can ease the activities of evaluation and utilization of *ex situ* germplasm.
7. There is urgent need for phytochemical and pharmacological evaluation of spices germplasm.
8. Documentation of valuable indigenous knowledge, registration of unique germplasm and DNA fingerprinting are of paramount importance in the fast changing scenario of Intellectual Property Rights.
9. Conservation of germplasm is an expensive activity. Precise estimation of cost of conservation in genebanks may vary. The relative cost of conservation should be estimated to adopt the appropriate strategy for long-term conservation. At the same time, potential economic benefits of utilization and safety of germplasm should not be ignored. Thus, cost-effective strategies are to be adopted based on the requirement of each crop.

References

Akhtar Husain, OP Virmani, SP Popli, LN Misra, MM Gupta, GN Srivastava, Z Abraham & AK Singh (1992) Dictionary of Indian Medicinal Plants. Central Institute of Medicinal and Aromatic Plants, Lucknow, 218p.

Antony JIX, PD Josan and ML Shankaranarayana (1998) Quantitative analysis of (-) hydroxy citric acid and (-) hydroxy citric acid lactone in *Garcinia* fruits and *Garcinia* products. *J. Food Sci. Tech.* **35**: 399-402.

Bhat SR, KPS Chandel and A Kackar (1994) *In vitro* induction of rhizomes in ginger *Zingiber officinale* Rosocoe. *Indian J. Exp. Biol.* **32**: 340-344.

Chacko KC and PK Chandrasekhara Pillai (1997) Seed characteristics and germination of *Garcinia gummi-gutta* (L.) Robs. *Indian Forester* **123**:123-126.

Kostermans AJGH (1983) The South Indian species of *Cinnamomum* Schaeffer (Lauraceae). *Bull. Bot. Survey India* **25**: 90-133.

Lewis YS and S Neelakandan (1965) (-) Hydroxy citric acid - the principal acid in the fruits of *Garcinia cambogia*. *Phytochemistry* **4**: 619.

Lowenstein JM (1971) Effect of (-) hydroxy citrate on fatty acid synthesis by rat liver. *J. Bio. Chem.* **246**: 629-632.

Mahendran P, AJ Vanisree and CS Devi (2002a) The antiulcer activity of *Garcinia cambogia* extract against indomethacin-induced gastric ulcer in rats. *Phytotheraphy Res.* **16**: 80-83.

Mahendran P, KE Sabitha and CS Devi (2002b) Prevention of HCl-ethanol induced gastro mucosal injury in rats by *Garcinia cambogia* extract and its possible mechanism of action. *Indian J. Exp. Biol.* **40**: 58-62.

Mathew L and Sarah T George (1995) Dormancy and storage of seeds in *Garcinia cambogia* Desr. (Kodampuli). *J. Tropical Agriculture* **33**: 77-79.

Murashige T and F Skoog (1962) A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Physiol. Plant.* **15**: 473-497.

Ravindran PN, K Nirmal Babu, B Sasikumar and KS Krishnamoorthy (2000) Botany and crop improvement of black pepper. In: Ravindran PN (ed) *Black Pepper, Piper nigrum*. Hardwood Academic Publishers, Amsterdam, the Netherlands, pp 23-142.

Ravindran PN, K Nirmal Babu, KV Peter, Z Abraham and RK Tyagi (2005) Spices. In: Dhillon BS, RK Tyagi, S Saxena and GJ Randhawa (eds) *Plant Genetic Resources: Horticultural Crops*, Narosa Publishers, New Delhi, India, pp 190-227.

Sarah T George, Baby Latha AK, Lyla Mathew K and CK Geetha (1992) Pattern of flowering and flower development in Kodampuli (*Garcinia cambogia* Desr). *Indian Cocoa, Arecanut and Spices J.* **16**: 68-70.

Singh NP (1993) Clusiaceae. In: B D Sharma and M Sanjappa (eds) *Flora of India*, Volume 3, Botanical Survey of India, Calcutta, pp 86-151.

Sullivan AC and J Triscari (1977) Metabolic regulation as a control for lipid disorders. Influence of (-) hydroxy citrate on experimentally induced obesity in the rodent. *Am. J. Clin. Nutr.* **30**: 767-776.

Sullivan AC, JG Hamiltan, ON Miller and VR Wheahkey (1972) Inhibition of lipogenesis in rat liver by (-) hydroxy citrate. *Arch. Biophys.* **150**: 183-190.

Sullivan AC, J Triscari, JG Hamiltan and ON Miller (1974) Effect of (-) hydroxy citrate upon the accumulation of lipid in the rat. *Appetite Lipids* **9**: 129-234.

Tyagi RK, SR Bhat and KPS Chandel (1998) *In vitro* conservation strategies for spices crop germplasm: *Zingiber, Curcuma* and *Piper* species. In: Mathew NM and CK Jacob (eds) *Developments in Plantation Crop Research*. Allied Publishers Limited, New Delhi, pp 77-82.

Tyagi RK, Yusuf A and P Dua (2000) Genetic stability of *in vitro*-conserved germplasm of *Curcuma* species. In: Proc. National Symp. on Prospects and Potentials of Plant Biotechnology in India in the 21st Century, Dept of Botany, Jai Narain Vyas University, Jodhpur, October 18-21, 2000, p 148.

Tyagi RK, Yusuf A, P Jeyaprakash and P Dua (2001) Effects of polyamines on *in vitro* conservation of *Vanilla planifolia* (Salisb.) Ames. *Indian J Plant Genet. Resour.* **14**: 300-302.

Tyagi RK, Yusuf A, P Dua, A Agrawal (2004) *In vitro* plant regeneration and medium-term conservation of eight wild species of *Curcuma*. *Biol. Plant.* **48**: 129-132.

Vavilov, NI (1926) Studies on the origin of cultivated plants. *Trudy Byûro prikl. Bot.* **16**: 139-248.

Velayudhan KC, KI Asha, SK Mithal and PL Gautam (1999) Genetic resource of turmeric and its relatives in India. In: Sasikumar B, B Krishnamoorty, J Rema, PN Ravindran and KV Peter (eds) *Biodiversity, Conservation and Utilization of Spices, Medicinal and Aromatic Plants*, Indian Institute of Spices Research, Calicut, Kerala, pp 101-109.

Velayudhan KC and RS Liji (2003) Preliminary screening of indigenous collections of turmeric against shoot borer and scale insect. *J. Spices Aromatic Crops.* **12**: 72-76.